Outcomes of Capitohamate Bone-Ligament-Bone Grafts for Scapholunate Injury

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Abstract

Purpose In an attempt to restore natural carpal kinematics more closely, bone-ligament-bone (BLB) grafts have been described for treating scapholunate (SL) injury. In this article we report the long-term results of capitohamate BLB autograft for the treatment of SL dissociation.

Methods The medical records of patients treated with capitohamate BLB grafts for SL dissociation were retrospectively reviewed. Twenty-three patients were available for evaluation. Patients were sent a Disabilities of the Arm, Shoulder, and Hand (DASH) and a Patient-Rated Wrist Evaluation (PRWE) questionnaire and returned for exam. Thirteen patients returned the questionnaire, and 12 wrists were examined. Range of motion, grip strength, pain, complications, return to work, and radiographic parameters were documented.

Results The average length of follow-up evaluation was 9.2 years. The average SL gap was 4.5 mm preoperatively and 3.6 mm at final follow-up. The average SL angle was 70 degrees preoperatively and 73 degrees at final follow-up. There was no statistically significant difference in preoperative versus postoperative flexion, extension, radial deviation, ulnar deviation, or grip strength. The average postoperative visual analog scale (VAS) score was 1.25 at rest and 3.58 with activity. The average Mayo Wrist Score was 66.8 preoperatively and 70.9 postoperatively ($p = 0.158$). The average postoperative PRWE was 20.5, and average postoperative DASH was 15.1. At final follow-up, four patients had no radiographic evidence of arthritis. Two patients had evidence of early-stage radiocarpal arthritis, four had evidence of midcarpal arthritis, and two had radiographic evidence of mild scaphotrapeziotrapezoid arthritis. One patient required a salvage procedure with four-corner fusion.

Discussion BLB reconstruction can be used to treat SL instability. At final follow-up, the majority of patients did not worsen clinically or functionally or require secondary salvage procedures; however, radiologic progression of arthritis was not prevented. These outcomes are comparable to midterm results of other SL reconstructive options; thus, we have abandoned this technique for other less technically demanding procedures.

Level of Evidence IV

Keywords
- bone-ligament-bone reconstruction
- scapholunate instability
- scapholunate injury
- wrist pain

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Scapholunate (SL) dissociation is a common form of carpal instability that can lead to wrist arthritis if left untreated.[1] The primary mechanism of injury is a fall on the outstretched hand with the wrist in ulnar deviation and supination.[2] Injury to the SL ligament results in altered wrist kinematics. Secondary attritional compromise to the external supporting ligamentous structures allows the scaphoid to rotate and sublux out of the scaphoid fossa, leading to eventual arthritis.[3]

In the acute phase, good results have been reported after direct repair of the dorsal scapholunate interosseus ligament (SLIL) and percutaneous pinning of the SL interval.[4–9] In the chronic setting, more extensive reconstruction is required to maintain the SL articulation and prevent excessive volar flexion of the scaphoid. Several surgical procedures have been described that utilize the dorsal wrist capsule or forearm tendons to stabilize scaphoid motion.[10–14] Although many of these reconstructions provide sufficient support to maintain the scaphoid and lunate temporarily in their (near-)anatomical positions, no true restoration of normal wrist kinematics is achieved, and long term results have been mixed.[9,15–21]

In an attempt to restore natural carpal kinematics more closely and maintain the SL relationship in the long term, SL reconstructions with bone-ligament-bone (BLB) grafts have been described. Several donor-sites have been proposed based on biomechanical studies, including the foot, hip, extensor retinaculum, and carpus.[22–32] However, apart from preliminary data and descriptions of technique, few long-term outcomes have been reported.[33] In this article we report the long-term results of capitohamate BLB autograft combined with a dorsal capsulodesis for the treatment of SL dissociation.

Methods

Study Subjects

This study was approved by our institution's institutional review board (IRB). Study inclusion criteria consisted of isolated use of capitohamate BLB autograft and dorsal capsulodesis for the treatment of symptomatic, chronic (greater than 6 weeks), flexible (reducible) SL instability without radiographic evidence of arthrosis in the scaphoid fossa of the radius. The flexibility of the deformity was determined intraoperatively by evaluating the reducibility of the SL interval. Only those deformities in which the SL interval could be reduced underwent BLB reconstruction. Exclusion criteria included patients undergoing concomitant wrist procedures in other area of the wrist besides the scaphoid; perilunate injuries; and any presurgical history of inflammatory arthritis. After a retrospective chart review, we identified 31 patients who underwent 32 (1 bilateral) capitohamate BLB autografts for symptomatic SL instability between October 1999 and November 2006 at our institution. Eight patients were excluded because they underwent additional wrist procedures at the time of the index operation. After IRB approval, the 23 eligible remaining patients were contacted by telephone and letter and invited to participate in the study. All were sent Disabilities of the Arm, Shoulder and Hand (DASH) and the Patient-Related Wrist Evaluation (PRWE) questionnaires and were asked to return to the office for wrist exam and radiographic evaluation. Eleven patients (12 wrists) completed the questionnaires and returned to clinic for a repeat evaluation. One patient completed the questionnaires but was unable to return for evaluation. The remaining 11 patients were either unwilling to complete the questionnaires, return for follow-up evaluation, or could not be reached.

Outcome Measures

For each patient, age, gender, hand dominance, occupation, mechanism of injury, grip strength, wrist range of motion (ROM) measurements, return to work status, and complications were recorded. Wrist radiographs included posteroanterior (PA), lateral, and oblique views. Radiographic measurements of SL angle, SL diastasis, radiolunate angle, and presence or absence of arthritis were recorded. All preoperative and postoperative radiographs were evaluated by two investigators (RVK and COB).

The following outcome questionnaires were administered to the patient: DASH, the PRWE and Visual Analog Scale (VAS). A Modified Mayo Wrist Score (MMWS) was calculated for each patient.[34] Pain was reported as *none, mild* (pain with exertion), *moderate* (pain with daily activity), and *severe* (pain limiting daily activity). Grip strength was measured using a dynamometer (Jamar, Clifton, NJ). The average of three measurements was recorded.

Surgical Technique

With the exception of two operations, all procedures were performed by the same surgeon (RAB). The procedure (►**Fig. 1a–c**) was initiated by exposure of the wrist through a longitudinal incision and a Mayo ligament-sparing capsulotomy.[35] Two to three Kirschner wire (K-wire) pins were used to reduce and maintain the position of the scaphoid and the lunate during the BLB procedure. A dorsal capitohamate BLB graft[36] was harvested and implanted in a trough created at the dorsal SL interval as described by Weiss.[24] The graft was secured with bone screws. Finally, a Mayo capsulodesis[35] was performed by rotating the proximal strip of the dorsal intercarpal ligament and attaching it to the dorsum of the lunate with sutures attached via a bone anchor or through drill holes. Patients were immobilized for 4 weeks. Protected motion was initiated at 4 weeks and continued until the pins were removed at 8 weeks. Strengthening exercises began at 8 weeks after pin removal, and full activity was allowed at 20 weeks.

Statistical Methods

The statistical significance of differences between preoperative and postoperative values was evaluated using the Wilcoxon signed rank-rank test. Data are expressed as means ± standard deviation. P values less than 0.05 were considered statistically significant.

Results

Of the 13 wrists evaluated, 3 had dynamic (visualized on arthroscopy) and 10 had static SL instability preoperatively.

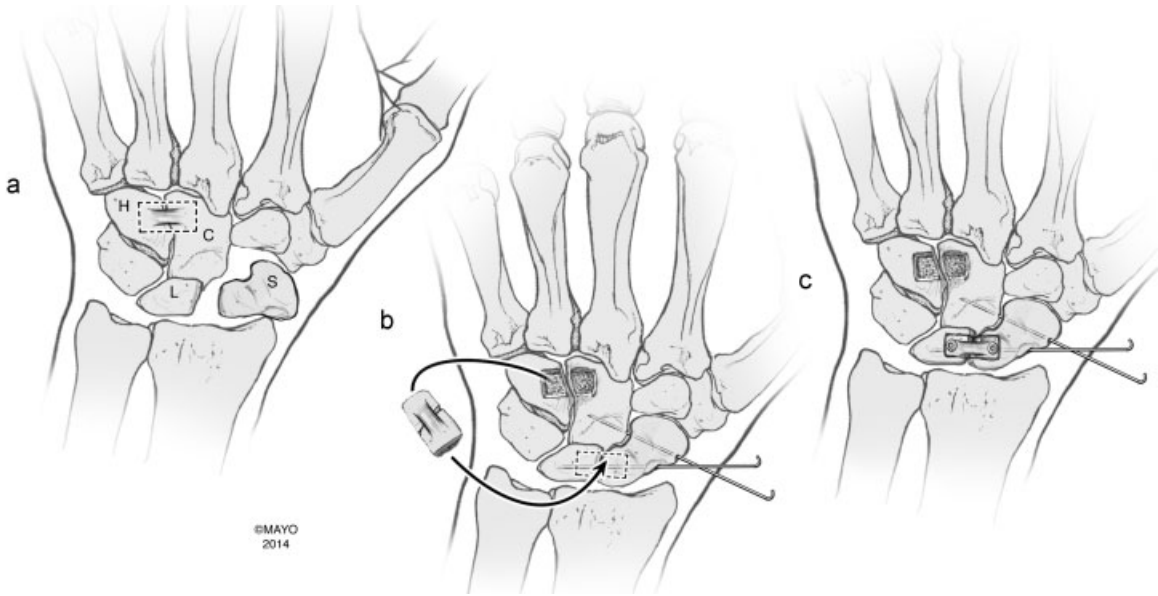

Fig. 1 Schematic representation of the BLB procedure. **(a)** The capitohamate BLB complex is harvested from the back of the wrist using a ligament-sparing capsulotomy. **(b)** The damaged dorsal SL ligament complex is removed. The SL relationship is restored and held in place with Kirschner wires (K-wires). **(c)** The capitohamate graft is then placed into the bone void and held in place with small screws.

Static instability was defined as the presence of SL diastasis ($>$ 2 mm) and an increased SL angle ($>$ 60 degrees) on preoperative radiographs. Dynamic instability was defined as normal scapholunate interval ($\leq$ 2 mm) and scapholunate angle ($\leq$ 60 degrees) on preoperative radiographs, but with evidence of SL instability during arthroscopy. Eleven patients were male and one was female. The mechanism of injury was a fall on outstretched hand or hyperextension injury in six wrists. For four wrists, the patients described a "twisting" mechanism that did not involve a fall. In one wrist, the injury occurred while lifting a heavy object. In one wrist the injury occurred while performing a tennis serve, and for one wrist the mechanism was unknown. The average age at surgery was 48 years (range 29–66 years). The average time from injury to surgery was 16.5 mos (range 2–72 mos). The average length of follow-up evaluation was 9.2 years (range, 5.0–11.7 years) (►**Table 1**). All but one patient underwent diagnostic arthroscopy before BLB reconstruction to verify SLIL injury. All

Table 1 Demographic data

Wrist	Age at surgery (years)	Gender	Hand dominance	Hand injured	Follow-up period (months)
1	63	M	R	R	142
2	64	M	R	L	130
3	66	M	R	L	128
4	41	M	L	R	112
5	47	M	L	R	114
6	42	M	R	R	61
7	48	M	R	R	136
8	51	M	R	R	89
9	29	M	R	L	81
10	44	M	R	L	136
11	32	M	R	R	121
12	52	F	R	L	62
13	53	M	R	L	104
Mean ($\pm$STD)	48.6 (11.4)				108 (27.8)

Wrists 1 and 2 are the right and left wrists of the same patient, respectively.
The patient with wrist 13 completed the questionnaires but was unable to present for clinical evaluation at final follow-up.
Abbreviations: F, female; L, left; M, male; R, right.

patients who underwent arthroscopic evaluation were diagnosed as having a class IV SLIL tear according to Geissler et al.,[37] with complete disruptions of the volar and dorsal SLIL. The patient who did not undergo arthroscopy was found to have a complete volar ligamentous tear and a partially intact dorsal SLIL at the time of surgery.

At final follow-up, five patients had a VAS score of 0 both at rest and after heavy activity. Three patients had a VAS score of 0 at rest that increased to a score of 3 with heavy activity. One patient had a VAS score of 1 at rest that increased to a VAS of 4 with heavy activity. Three patients had a VAS of greater than 3 at rest (range 3–6); all three of these patients reported a VAS that increased to 10 with heavy activity. The average postoperative VAS score was 1.25 at rest and 3.58 with activity. Of the three patients with VAS greater than 3 at rest, one patient had an early K-wire removal due to pin-site infection; another patient decided to undergo a salvage procedure with four-corner fusion 81 months after his BLB procedure.

At final follow-up, four patients had no radiographic evidence of arthritis (►**Fig. 2a–f**). Two patients had evidence of early-stage radiocarpal arthritis. Four patients had evidence of midcarpal arthritis. Two patients had radiographic evidence of mild scaphotrapeziotrapezoid arthritis, and one patient had significant ulnar lunate translocation. The average SL gap was 4.5 mm preoperatively, 2.5 mm postoperatively, and 3.6 mm at final follow-up. The average SL angle was 70 degrees preoperatively, 54 degrees postoperatively, and 73 degrees at final follow-up (►**Table 2**). There was no statistically significant difference in preoperative versus postoperative flexion ($p = 0.67$), extension ($p = 0.20$), radial deviation ($p = 0.76$), ulnar deviation ($p = 0.68$), or grip strength ($p = 0.69$) (►**Table 3**).

The average preoperative MMWS was 66.8 (range 45–80). The average postoperative MMWS was 70.9 (range 40–95). There was no statistically significant difference between preoperative and postoperative MMWS ($p = 0.16$). The average postoperative PRWE was 20.5 (range 0–54). The average postoperative DASH was 15.1 (range 0–49.2). The average postoperative Work DASH was 12.0 (range 0–100) (►**Table 4**). One patient, who underwent four-corner fusion, was working as a cabinetmaker at the time of injury. He was unemployed at final follow-up because of inability to work secondary to his wrist discomfort. The remaining patients did not require a change of employment because of their injury.

Six patients had complications postoperatively. One patient developed a pin tract infection that required antibiotics and pin removal at 4 weeks. One patient developed a pyogenic granuloma at his pin site that required pin removal at 6 weeks. One patient developed symptoms that were consistent with complex regional pain syndrome, type 1. Her symptoms resolved with peripheral nerve blocks and physical therapy. There were three instances of hardware failure. One patient

Fig. 2 **(a,b)** AP and lateral radiographs of wrist 12, demonstrating SL instability before capitohamate BLB procedure. **(c,d)** Immediate postoperative AP and lateral radiographs after capitohamate BLB procedure in wrist 12, demonstrating reduction of the SL articulation. **(e,f)** AP and lateral radiographs at final follow-up (142 months postoperatively) in wrist 12, demonstrating maintenance of the SL relationship and preservation of joint space.

Table 2 Radiographic parameters

Wrist	Pre-SLA (°)	Post-SLA (°)	Final SLA (°)	Pre-SLG (mm)	Post-SLG (mm)	Final SLG (mm)	Arthritis on Most Recent Radiograph?
1	47	47	50	2	2	2	No
2	47	47	85	2	2	2	Yes (SLAC 3)
3	58	47	60	5.5	2	3	Yes (SLAC 3)
4	75	47	76	4	2	3	No
5	80	80	85	4	3.5	3.5	Yes (mild STT)
6	55	68	90	1	1	2	Yes (SLAC 1)
7	63	47	50	7.8	2	5	Yes (SLAC 2)
8	85	54	75	8	2.4	6	No
9	77	48	70	7	2.1	7	Yes (SLAC 3)
10	70	47	69	4	2	3.5	Yes (SLAC 3 and STT)
11	80	47	88	5	2	4	Yes (SLAC 1)
12	75	66	80	3	2.8	2.8	No
13	70	54	n/a	5	2.4	n/a	n/a
Mean (±SD)	67.8 (12.7)	53.7 (10.8)	73.2 (13.8)	4.5 (2.21)	2.2 (0.56)	3.7 (1.6)	

Abbreviations: Post, postoperative; Pre, preoperative; SLA, scapholunate angle; SLG, scapholunate gap.

required a secondary procedure, undergoing four-corner fusion for symptomatic scapholunate advanced collapse (SLAC) arthritic changes at 81 months after his original procedure. Radiographs demonstrated evidence of BLB hardware failure with screw migration before the secondary procedure was performed (►**Fig. 3a,b**). Two additional patients had evidence of BLB hardware failure at final follow-up. One of these patients had radiographic evidence of screw migration in addition to disease recurrence and development of radiocarpal arthrosis (►**Fig. 4a–c**). The other patient had evidence of screw fracture at final radiographic follow-up; however, this patient had a well-maintained SL relationship (SL gap 2 mm, SL angle 50 degrees) without radiographic evidence of arthritic change.

Discussion

We have previously demonstrated that the capitohamate autograft exploiting the dorsal ligament causes minimal donor site instability thanks to preservation of the deep and palmar capitohamate as well as the carpometacarpal and intermetacarpal ligaments.[32,36] In a recent cadaveric study, the biomechanical properties of the capitate–trapezoid, trapezoid–second metacarpal, third metacarpal–carpal, 4–5 extensor retinaculum, and capitohamate autografts were compared with each other and to the native dorsal SLIL.[38] The dorsal capitohamate ligament was shown to have the closest properties to the native dorsal SL ligament, and the capitohamate BLB graft was the only graft shown to have no significant difference from the native SLIL in terms of load to failure. The other grafts tested were significantly weaker.[38]

The average follow-up for patients undergoing capitohamate BLB graft in our series is 9.2 years. The long-term results are comparable to midterm results of other soft tissue reconstructions.[15,17,21] As with other treatment modalities, results are not always predictable, and radiographic SL parameters were not maintained long-term. A possible explanation is that capitohamate BLB reconstructions address only the dorsal component of the SLIL. Indeed, the dorsal SLIL has been shown to contribute most to scapholunate stability; however, the volar SL ligament is also an important stabilizer of this articulation.[39]

In our series, the majority of patients undergoing capitohamate BLB graft reported improvement of preoperative pain levels and demonstrated low postoperative levels of disability on the DASH and PRWE questionnaires. Five patients were pain-free at final follow-up. There was radiographic evidence of hardware failure in three patients at final follow-up. Although one of these patients had no evidence of disease recurrence or development of arthritis, the remaining two patients demonstrated recurrent scapholunate instability and radiocarpal arthritic change, and one required a salvage operation with four-corner fusion. It is possible that hardware failure contributed to BLB failure and the need for salvage operation. Further investigation of alternative means of graft fixation is needed to determine whether such failure and resultant need for subsequent procedures can be avoided. Newer options for carpal fixation, including temporary spanning SL screws, may provide a better means of graft fixation as well as carpal fixation.

There are several limitations in our study, including its retrospective design and the fact that our study was not

Table 3 Range of motion

Wrist	Pre-Flex (°)	Final-Flex (°)	Pre-Ext (°)	Final-Ext (°)	Pre-UD (°)	Final-UD (°)	Pre-RD (°)	Final-RD (°)	Pre-GS (kg)	Final-GS (kg)
1	65	50	75	65	45	45	20	10	54	28
2	45	50	50	65	25	45	25	15	51	24
3	42	35	40	55	14	30	12	22	34	50
4	75	50	70	75	45	25	5	20	52	54
5	70	55	70	50	31	40	18	30	51	4
6	55	20	63	60	26	10	19	3	24	30
7	50	65	50	75	30	45	30	25	22	18
8	31	50	27	70	15	35	13	10	6	18
9	30	20	45	55	23	30	16	10	29	28
10	50	60	75	45	30	35	25	10	38	38
11	70	63	65	84	55	34	15	13	43	34
12	21	65	19	75	19	40	13	15	7	34
13	70	n/a	75	n/a	45	n/a	20	n/a	34	n/a
Mean (±SD)	52 (17.6)	49 (15.8)	56 (18.8)	65 (11.8)	31(12.3)	35 (10.1)	18 (6.6)	15 (7.7)	34.2 (16.2)	30 (13.7)

Abbreviations: Ext, extension; Flex, flexion; GS, grip strength; Post, postoperative; Pre, preoperative; RD, radial deviation; UD, ulnar deviation.

Table 4 Outcome measures

Wrist	MMWS (pre)	MMWS (post)	PRWE	DASH	Work DASH
1	80	90	0	0	0
2	80	75	0	0	0
3	65	75	4.5	1.7	0
4	80	90	10	7.5	0
5	80	95	9.5	3.3	0
6	70	40	52	48	0
7	60	80	0	0.9	0
8	50	65	9	10	0
9	50	50	45	43.5	50
10	45	55	54	49.2	100
11	75	65	50	24.2	6.3
12	67	71	23.5	6.7	0
13	67	71	8.5	0.8	0
Mean (±STD)	66.8 (12.5)	70.9 (16.1)	20.5 (21.6)	15.1 (19.2)	12.0 (29.8)

Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand score; MMWS, Modified Mayo Wrist Score; Post, postoperative; Pre, preoperative; PRWE, Patient Related Wrist Evaluation.

significantly powered to investigate a difference in outcomes between patients with static and dynamic SL instability. As is the case with most reports on SLIL reconstruction, this series comprises relatively few patients. Furthermore, several patients were not available for evaluation at final follow-up. However, this is one of the largest reported series of BLB reconstructions and, to our knowledge, is the only investigation reporting the outcomes of reconstruction with the capitohamate BLB grafting technique.

Given our results, we have abandoned this technique in favor of other, less technically demanding procedures, as results appear equivalent to those of tenodesis procedures. This technique for BLB reconstruction can be considered as a second-line treatment in patients who have failed tenodesis procedures. We *do* believe that BLB grafts are a positive addition to the hand surgeon's armamentarium for the treatment of chronic SL dissociation, but it may benefit from newer fixation devices or different orientations in graft placement.

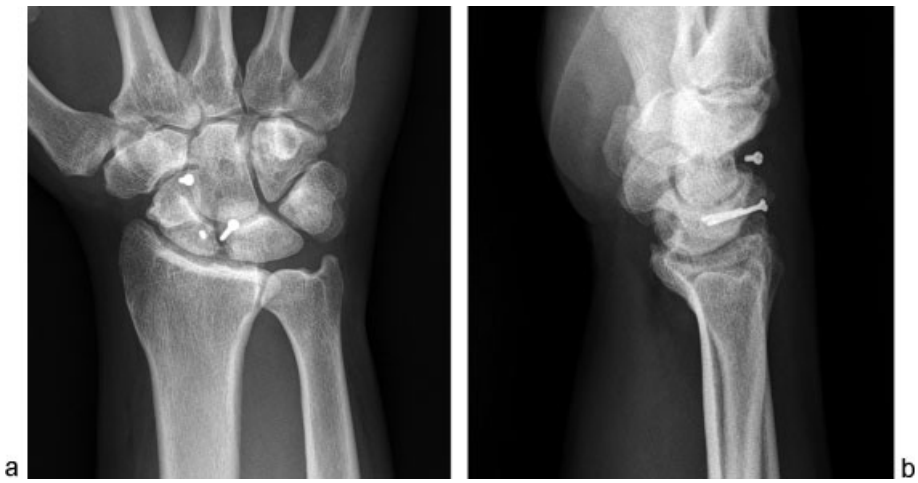

Fig. 3 **(a,b)** AP and lateral radiographs of wrist 6, 81 months after the original procedure, demonstrating screw breakage and migration and development of SLAC changes. This patient went onto a scaphoidectomy and four-corner fusion.

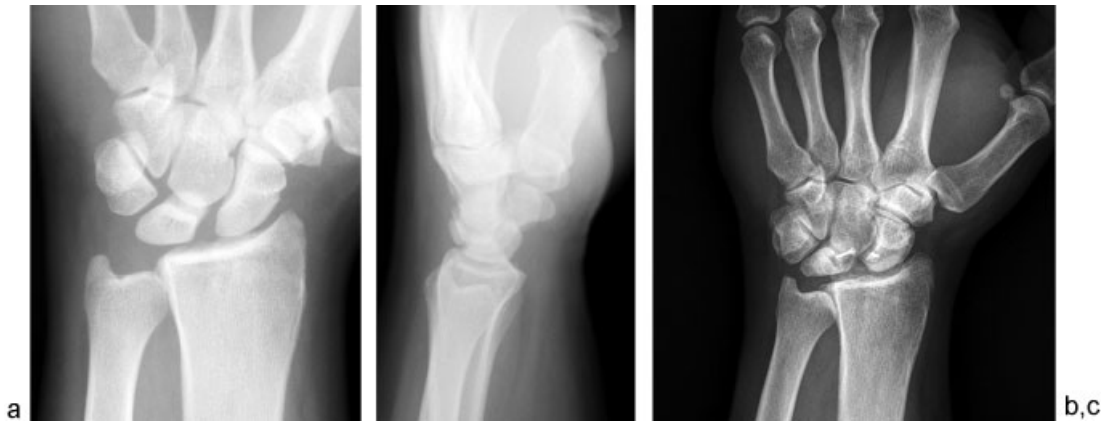

Fig. 4 **(a,b)** AP and lateral radiographs of wrist 9 demonstrating SL instability before capitohamate BLB procedure. **(c)** AP radiograph of wrist 9 at 54 months after original procedure, demonstrating screw migration and development of SLAC arthritis.

Conflict of Interest
None

References

1 Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am 1984; 9(3):358–365
2 Mayfield JK. Mechanism of carpal injuries. Clin Orthop Relat Res 1980;(149):45–54
3 Watson H, Ottoni L, Pitts EC, Handal AG. Rotary subluxation of the scaphoid: a spectrum of instability. J Hand Surg [Br] 1993;18(1): 62–64
4 Weiss APC, Sachar K, Glowacki KA. Arthroscopic debridement alone for intercarpal ligament tears. J Hand Surg Am 1997; 22(2):344–349
5 Ruch DS, Poehling GG. Arthroscopic management of partial scapholunate and lunotriquetral injuries of the wrist. J Hand Surg Am 1996;21(3):412–417
6 Whipple TL. The role of arthroscopy in the treatment of scapholunate instability. Hand Clin 1995;11(1):37–40
7 Darlis NA, Kaufmann RA, Giannoulis F, Sotereanos DG. Arthroscopic debridement and closed pinning for chronic dynamic scapholunate instability. J Hand Surg Am 2006;31(3):418–424
8 Walsh JJ, Berger RA, Cooney WP. Current status of scapholunate interosseous ligament injuries. J Am Acad Orthop Surg 2002; 10(1):32–42
9 Lavernia CJ, Cohen MS, Taleisnik J. Treatment of scapholunate dissociation by ligamentous repair and capsulodesis. J Hand Surg Am 1992;17(2):354–359
10 Almquist EE, Bach AW, Sack JT, Fuhs SE, Newman DM. Four-bone ligament reconstruction for treatment of chronic complete scapholunate separation. J Hand Surg Am 1991;16(2):322–327
11 Brunelli GA, Brunelli GR. A new surgical technique for carpal instability with scapholunate dissociation. Surg Technol Int 1996;5:370–374
12 Blatt G. Capsulodesis in reconstructive hand surgery. Dorsal capsulodesis for the unstable scaphoid and volar capsulodesis following excision of the distal ulna. Hand Clin 1987;3(1):81–102
13 Viegas SF, Dasilva MF. Surgical repair for scapholunate dissociation. Tech Hand Up Extrem Surg 2000;4(3):148–153
14 Van Den Abbeele KL, Loh YC, Stanley JK, Trail IA. Early results of a modified Brunelli procedure for scapholunate instability. J Hand Surg [Br] 1998;23(2):258–261
15 Gajendran VK, Peterson B, Slater RR Jr, Szabo RM. Long-term outcomes of dorsal intercarpal ligament capsulodesis for chronic scapholunate dissociation. J Hand Surg Am 2007;32(9): 1323–1333
16 Moran SL, Cooney WP, Berger RA, Strickland J. Capsulodesis for the treatment of chronic scapholunate instability. J Hand Surg Am 2005;30(1):16–23
17 Moran SL, Ford KS, Wulf CA, Cooney WP. Outcomes of dorsal capsulodesis and tenodesis for treatment of scapholunate instability. J Hand Surg Am 2006;31(9):1438–1446
18 Muermans S, De Smet L, Van Ransbeeck H. Blatt dorsal capsulodesis for scapholunate instability. Acta Orthop Belg 1999;65(4): 434–439
19 Szabo RM, Slater RR Jr, Palumbo CF, Gerlach T. Dorsal intercarpal ligament capsulodesis for chronic, static scapholunate dissociation: clinical results. J Hand Surg Am 2002;27(6): 978–984
20 Wyrick JD, Youse BD, Kiefhaber TR. Scapholunate ligament repair and capsulodesis for the treatment of static scapholunate dissociation. J Hand Surg [Br] 1998;23(6):776–780
21 Talwalkar SC, Edwards ATJ, Hayton MJ, Stilwell JH, Trail IA, Stanley JK. Results of tri-ligament tenodesis: a modified Brunelli procedure in the management of scapholunate instability. J Hand Surg [Br] 2006;31(1):110–117
22 Cuénod P. Osteoligamentoplasty and limited dorsal capsulodesis for chronic scapholunate dissociation. Ann Chir Main Memb Super 1999;18(1):38–53
23 Cuénod P, Charrière E, Papaloïzos MY. A mechanical comparison of bone-ligament-bone autografts from the wrist for replacement of the scapholunate ligament. J Hand Surg Am 2002;27(6): 985–990
24 Weiss APC. Scapholunate ligament reconstruction using a bone-retinaculum-bone autograft. J Hand Surg Am 1998;23(2): 205–215
25 Davis CA, Culp RW, Hume EL, Osterman AL. Reconstruction of the scapholunate ligament in a cadaver model using a bone-ligament-bone autograft from the foot. J Hand Surg Am 1998;23(5): 884–892
26 Harvey EJ, Hanel D, Knight JB, Tencer AF. Autograft replacements for the scapholunate ligament: a biomechanical comparison of hand-based autografts. J Hand Surg Am 1999;24(5): 963–967
27 Harvey EJ, Hanel DP. Bone-ligament-bone reconstruction for scapholunate disruption. Tech Hand Up Extrem Surg 2002;6(1): 2–5

28 Hofstede DJ, Ritt MJ, Bos KE. Tarsal autografts for reconstruction of the scapholunate interosseous ligament: a biomechanical study. J Hand Surg Am 1999;24(5):968–976
29 Lutz M, Haid C, Steinlechner M, et al. Scapholunate ligament reconstruction using a periosteal flap of the iliac crest: a biomechanical study. Arch Orthop Trauma Surg 2004;124(4):262–266
30 Müller M, Reik M, Sauerbier M, Germann G. A new bone-ligament-bone autograft from the plantar plates of the toes and its potential use in scapholunate reconstruction: an anatomical study. Ann Plast Surg 2008;61(4):463–467
31 Svoboda SJ, Eglseder WA Jr, Belkoff SM. Autografts from the foot for reconstruction of the scapholunate interosseous ligament. J Hand Surg Am 1995;20(6):980–985
32 Ritt MJ, Berger RA, Kauer JM. The gross and histologic anatomy of the ligaments of the capitohamate joint. J Hand Surg Am 1996; 21(6):1022–1028
33 Soong M, Merrell GA, Ortmann F IV, Weiss AP. Long-term results of bone-retinaculum-bone autograft for scapholunate instability. J Hand Surg Am 2013;38(3):504–508
34 Amadio PC, Berquist TH, Smith DK, Ilstrup DM, Cooney WP III, Linscheid RL. Scaphoid malunion. J Hand Surg Am 1989;14(4): 679–687
35 Berger RA, Bishop AT, Bettinger PC. New dorsal capsulotomy for the surgical exposure of the wrist. Ann Plast Surg 1995;35(1): 54–59
36 Ritt MJ, Berger RA, Bishop AT, An KN. The capitohamate ligaments. A comparison of biomechanical properties. J Hand Surg [Br] 1996; 21(4):451–454
37 Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am 1996; 78(3):357–365
38 Gay AM, Thoreson A, Berger RA. Biomechanical comparison of the hand-based transplant used in bone-tissue-bone scapho-lunate ligament reconstruction. Chir Main 2014;33(1):23–28
39 Berger RA, Imeada T, Berglund L, An KN. Constraint and material properties of the subregions of the scapholunate interosseous ligament. J Hand Surg Am 1999;24(5):953–962